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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 603

CLERGET 100 hp HEAVY-OIL ENGINE

By Pierre Léglise

From L'Aéronautique, November, 1930

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CLERGET 100 hp HEAVY-OIL ENGINE*

By Pierre Léglise

"L'Aéronautique" has already given a summary (No. 126, November, 1929, p. 369) of the 100 hp Clerget heavy-oil engine (Fig. 1), of which five examples are under construction. A complete technical description of the engine can now be given. Its general characteristics are: 9 cylinders, bore 120 mm (4.72 in.), stroke 130 mm (5.12 in.), four-stroke-cycle engine, rated power limited to 100 hp at 1800 r.p.m.; weight 228 kg (503 lb.); propeller with direct drive; air-cooled.

Crankcase and Cylinders

The crankcase is entirely of forged steel without welding. It is designed for easy machining of all its parts without special tools. Owing to the homogeneity of the steel, the ultimate resistance could be calculated with much greater accuracy than that of light alloys. The use of steel likewise insures the same expansion coefficient for crankcase and cylinders.

The cylinders (Fig. 3) are forged steel with machined cooling fins. Their lower end is provided with a square-section thread for screwing into the crankcase (with locking screw).

*"Le moteur Clerget 100 hp à huile lourde," a copyrighted article in L'Aéronautique, November, 1930, pp. 391-396.

The flat cylinder head is in one piece with no joints nor welded parts. The injection valve is located in the center of the cylinder head between the intake and exhaust valves. An aluminum case, housing the intake and exhaust valves, is secured to the cylinder head by four bolts, two of which carry the brackets of the rocker arms.

Draining of oil and decompression.-- In engines with radial cylinders the lower cylinders may contain, after a stop, a certain amount of oil. If the engine has a high compression, the oil thus accumulated may occupy a considerable portion of the combustion chamber, the volume of the latter being thus greatly reduced. In starting the engine, this sometimes results in excessive pressure, which may cause accidents. In the Clerget engine, a system of rollers (Fig. 8), controlled by the pilot, lifts all the exhaust valves simultaneously, thus allowing the oil to drain off after the engine stops.

Moreover, the following advantages are afforded by the resulting decompression:

Possibility, after a glide, of starting the engine again under the action of the propeller, by diving;

Easier adjustment;

Absolutely sure stopping, when injection components get out of adjustment, or jammed controls prevent their operation.

The exhaust valves do not occupy the same position on all the cylinders, being symmetrically arranged with respect to the

vertical plane passing through the engine axis at the lowest point of the bottom cylinders. Complete evacuation of residual oil during operation and at rest is thus facilitated.

Moving Parts

Pistons (Fig. 6).— Of ordinary light alloy; piston pin free both in its bosses and in the small end of the connecting rod; four piston rings and one scraper ring. A considerable number of patents have been taken out during the last few years for special shapes of intake domes, combustion or precombustion chambers, cut-out sections, piston deflectors, etc. The purpose of these shapes is to produce the degree of turbulence required for the combustion in heavy-oil engines. Most of them, however, present disadvantages which balance the anticipated increase in efficiency, perhaps on account of their complexity.

Clerget thinks that turbulence can be produced by very simple means, namely a natural intake, the shape of the piston and the distribution of the fuel during combustion. The form of his piston is hemispherical, and the sheet-type injection at the center of this cavity insures good combustion in the vortices produced by the piston when it approaches the top of the cylinder. Contact of the fuel with the cylinder walls being avoided, the carbon deposits do not adhere and are ejected during the exhaust. These arrangements have given excellent results at high speeds.

Connecting rods.-- The system comprises a master connecting rod and auxiliary or secondary rods (Fig. 4). All friction surfaces are lubricated under pressure, and the auxiliary connecting rods are interchangeable.

Crankshaft.-- The crankshaft is in two parts connected by a conical joint (Fig. 5). The parts are locked together by a central screw with differential thread. Owing to this screw, the parts in contact are automatically separated when it is loosened, which greatly facilitates the dismantling of the engine from the front. The rear portion of the crankshaft, forming a crankpin, controls the fuel-pump mechanism, while its front portion carries the distribution.

Fuel System

Each cylinder is provided with a pump, the upper part of which projects from the crankcase. The fuel is conveyed to the injector through a copper pipe of 2/4 mm (0.08/0.16 in.) withstanding pressures of 1000 kg/cm² (14220 lb./sq.in.). If higher pressures are accidentally developed, the pipe bursts and protects more delicate parts. A second pipe, also of copper, leads the fuel back from the injector to the supply of oil in which the intake orifices of the pumps are submerged.

Control mechanism of fuel pump.-- The engine being of the four-stroke-cycle type, the pumps must operate in the natural order of ignition of a radial engine: 1, 3, 5, etc. A cam 4

(Figs. 7 and 9) is mounted on the crankshaft by means of a helicoidal track which permits changing its setting for the purpose of advancing or retarding the injection. This cam is not in direct contact with the pump tappets 1. It turns inside of a crown ring 3, which carries four slides: 2, 5, 6 and 7 (Fig. 9). The crown ring rotating in the opposite direction to the crankshaft and at 1/8th of its speed, the four slides intervene, at the desired moment, between the pump tappets (e.g. 1) and the cam 4.

Let the pump tappet, a slide and the cam be on the vertical axis of the first cylinder (Fig. 10) at the time 0. The cam falls in line with the axis of the third cylinder after rotating 80° , and the slide, which was first horizontal and on the right, reaches the same position after 10° . Since these slides turn exactly eight times slower than the cam, the coincidence takes place again opposite the tappet of the third cylinder, and so on.

Each tappet has a sector insuring its contact with the cam, in spite of variations in the setting of the latter, as required for advancing the injection. After the passage of the cam, the slides are normally drawn back by the pump springs; in case of a breakage of the latter, the recoil is effected by fixed cams 8 (Fig. 9).

A single cam being used for all the cylinders, they all receive the same injection. Besides, since the cam rotates at the same speed as the crankshaft, the injection is rapid without

requiring the use of a cam with a sharp profile, which causes hammering. Lastly, the accuracy of injection is not affected by a variation in the cam setting.

Differential-reaction injection pumps.— The injection pumps (Fig. 11) are entirely submerged in the fuel, their unpriming being thus avoided. A small gear pump, driven by the engine and located externally between the two lower cylinders, insures a continuous fuel circulation through a filter. The fuel then returns to the tank after passing through a sight gauge. This circulation insures the removal of any air which may be in the oil. It is essential that there should be no intake of air under the sudden suction of the pumps.

Variation of the Output.— Piston 7 (Fig. 11) has a constant stroke, independent of the output. Cylinder 2, controlled by the pilot through the lever A and finger 3, slides between the barrel of the pump 1, which emerges from the crankcase, and the extension of the valve case 4. The intake orifice 6 in the side of the cylinder can therefore be shifted with respect to the dead centers of the piston, permitting a variation in the amount of fuel drawn in and hence in the output.

There being only one intake orifice, the functioning is correct, even with a considerable clearance of the piston, since the force of compression actually presses the latter against the orifice.

The valve housings are easily removable, which makes it easy to check the position of the pistons on the airplane, thus obviating the need of returning an engine to the bench for replacing any part of the injection system.

Differential reaction.— The valve case 4 has a diameter D (Fig. 11) slightly greater than the diameter d of piston 7. Cylinder 2 therefore forms directly below the valve case and in the neighborhood of the upper dead center of the piston, an annular shelf or flange indicated by the two small arrows. Under the action of the compressive force R exerted on this flange, cylinder 2 is automatically pressed against its control finger 3 and the slack in the transmission, all the way from the pilot's cockpit, is thus taken up. This arrangement permits of using pumps of ordinary precision, which can be satisfactorily operated by any pilot.

Device for regulating the output of the pumps.— Each cylinder of a fuel-injection engine is supplied with a definite amount of fuel. Theoretically, a more uniform fuel distribution is therefore achieved than in an ordinary gasoline engine where one carburetor supplies several cylinders through curved pipes, usually of unequal lengths.

It is necessary, however, that minor operations of replacement (replacing an obstructed nozzle, a damaged pump, etc.) and adjustment (wear of control or transmission gears) can be performed on the airplane. Each cylinder of the 100 hp Clerget

engine has an external device by which the relative output of its pump can be regulated.

A (Fig. 12) is the control lever of the pump cylinder (same letters with subscripts in Fig. 13). This lever is connected by the rod T (B_1C_1) to a crown wheel, movable about the crankcase. When this wheel is rotated by the pilot, the lever A passes from A_1 to A_2 (Fig. 13) through an angle α , while the ends B and C pass from B_1 to B_2 and from C_1 to C_2 respectively. This maneuver corresponds to the operation of the butterfly valve in a carburetor engine.

The end C carries two independent adjustments:

Low-speed adjustment.— The length of the rod T can be changed at C by a thread, which fixes the initial position A_1 of the lever A;

High-speed adjustment.— The pin X, which forms the hinge joint of rods T and A, slides in a curved groove in A, described with B as the center. In order to increase the output of a pump at full speed, a certain increment β must be added to the angle of rotation α of lever A. Obviously it is only necessary to lower the axis X in its groove. C_1 moves to C'_1 and, for an equal displacement of the end B, from B_1 to B_2 , the end C travels from C_1 to C_2 , thus providing the required angular increment β .

Note that the high-speed adjustment does not interfere with the low-speed adjustment, since C passes from C_1 to C'_1 along the arc having the rod T as its radius.

Injection nozzles.— The injection nozzle used (Fig. 15) consists essentially of a small valve held against its seat by a spring. Grooves, nearly tangent to the outlet circumference, are provided in the contact portion of the valve head. The reaction of the high-pressure jets imparts a certain rotation to the valve, which cleans the grooves and prevents their obstruction. Consequently, their depth was reduced, being now only 0.15 mm (0.006 in.), so that penetrating jets are produced at all speeds. Moreover, the small depth of the grooves permits of increasing their number and thus improving the fuel distribution. Lastly, the tangential injection produces a turbulence which is always proportional to the speed. Figure 14 shows the first type of injection valve used.

Lubrication

Oil is circulated by a double gear pump. The first pump draws the oil from the tank and forces it into the crankshaft through a special joint described below. The pressure, recorded by a manometer, is limited by an adjustable return valve. The second pump drains the crankcase and returns the oil to the tank.

The special joint (Fig. 16) consists of two cylindrical telescoping sleeves 2 and 4 provided with hemispherical ends resting in housings of the same shape, one in the fixed portion which carries the oil intake 1, and the other in the crankshaft 5. Contact is assured by the internal pressure and by the spring 3

Starting

The first engines were designed for training airplanes and it was deemed advisable to avoid the complication of a cockpit starter. The starting is instantaneous with rubber-cord starters available on all flying fields.

The engine runs on a gas oil commonly used for stationary engines. This oil has a density of 0.860, emits no inflammable vapors below 90° C, and has a heat content of 9500 calories. However, the engine can run on any other heavy oil. A power of 150 hp was reached in tests, the engine being amply calculated.

A description of the 200 hp Clerget heavy-oil engine (Fig. 2) will be given shortly. This engine has had the benefit of experience and, while it affords all the safety of prudent technical development, it is lighter and has a lower fuel consumption. The pumps and their control mechanism have been moved to the front in order to enable the mounting of a super-charger on the rear plate. The bore is 130 mm (5.12 in.) and the stroke 170 mm (6.7 in.), weight 310 kg (683.4 lb.), power 208 hp at 1700 r.p.m.

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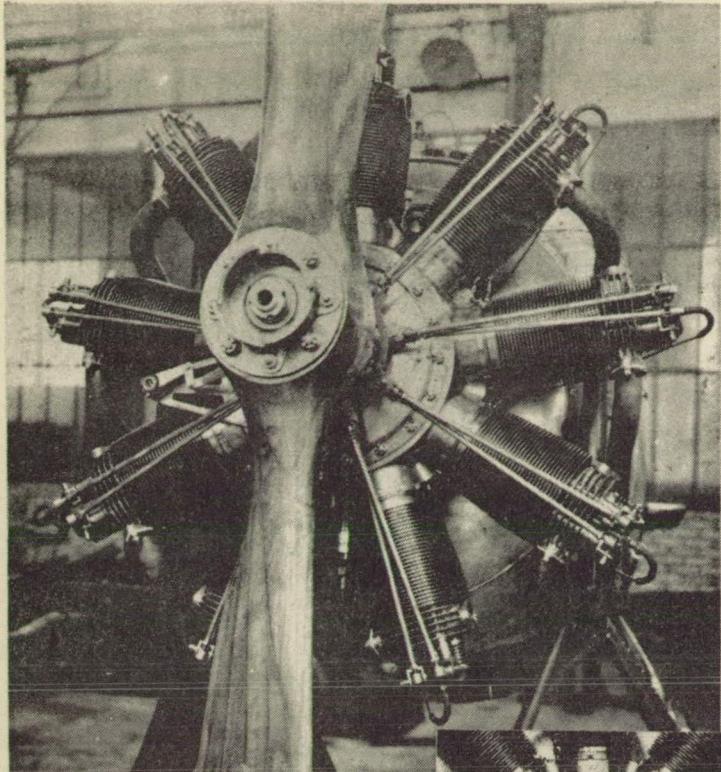
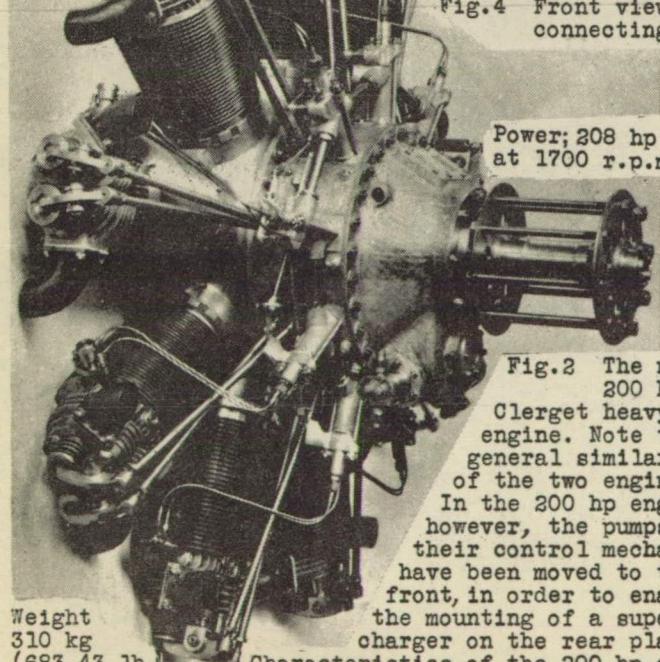


Fig.1 The 100 hp Clerget heavy-oil engine.



Fig.4 Front view of connecting rods.



Weight
310 kg
(683.43 lb.)

Characteristics of the 200 hp engine,
bore 130mm (5.118in) stroke 170mm (6.693in)

Power: 208 hp
at 1700 r.p.m.

Clerget heavy oil
engine. Note the
general similarity
of the two engines.
In the 200 hp engine,
however, the pumps and
their control mechanism
have been moved to the
front, in order to enable
the mounting of a super-
charger on the rear plate.

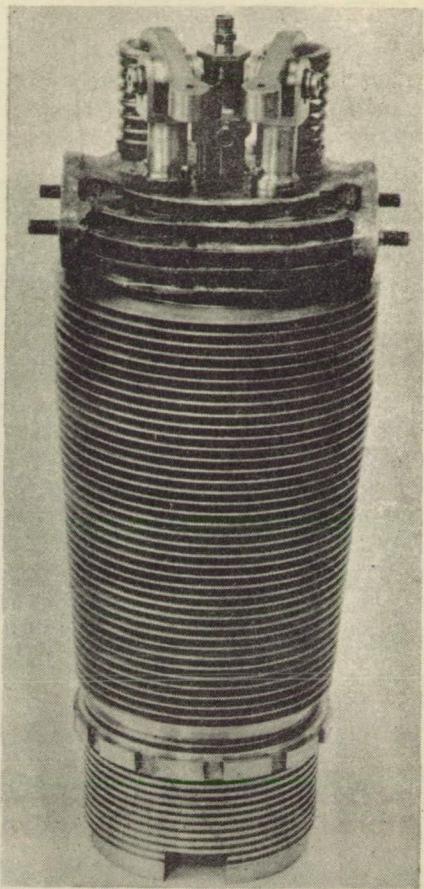


Fig.3 Cylinder

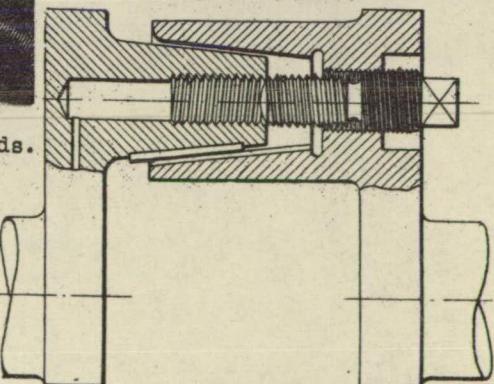
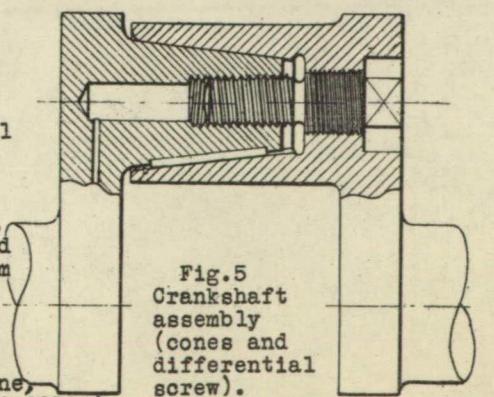


Fig.5
Crankshaft
assembly
(cones and
differential
screw).



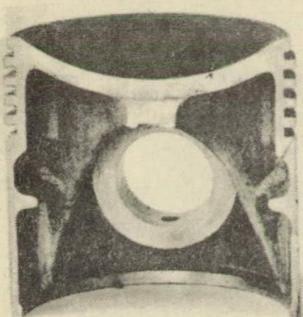


Fig.6 Piston.

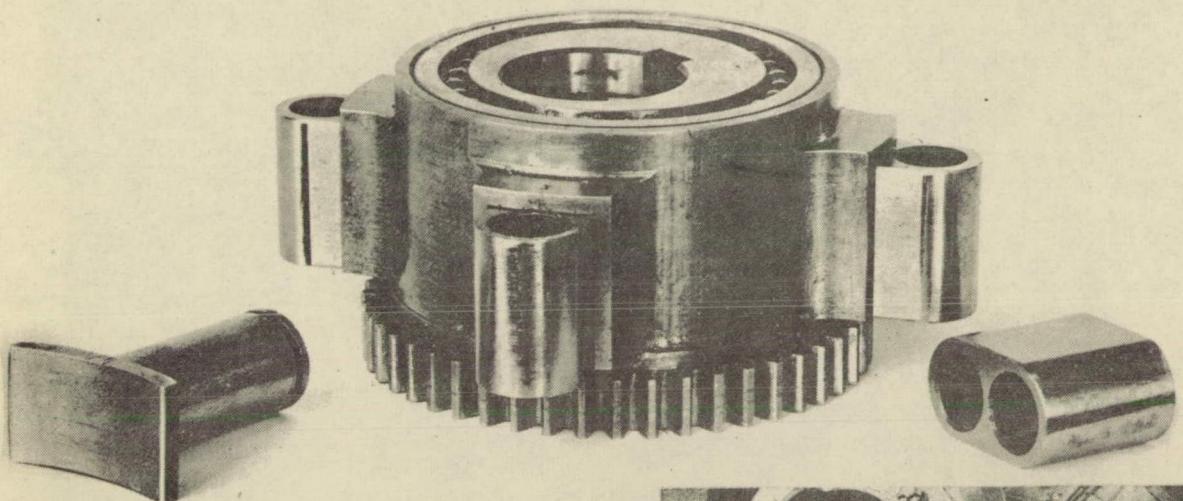


Fig.7 Pump-control wheel, tappet
and slide (1 and 2, Fig.9.)

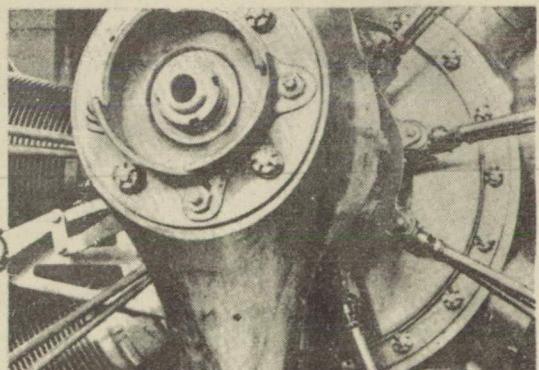


Fig.8 Decompression
mechanism.

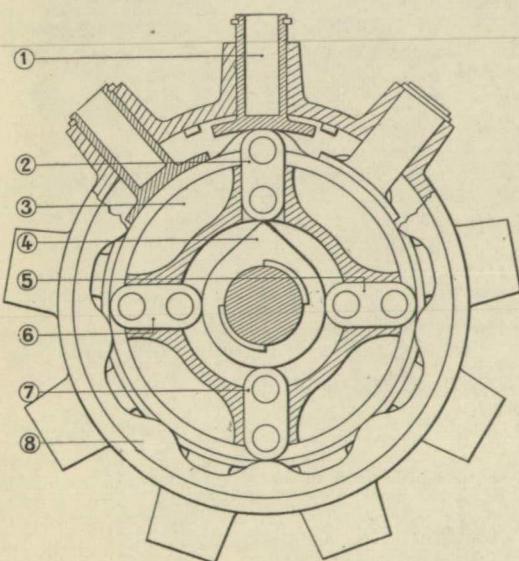


Fig.9 Diagram of pump-control mechanism.
1, tappet; 2,5,6 and 7, slides fitted
in ring 3; 4, cam integral with crankshaft;
8, ring with fixed cams pushing slides back
in case of failure of pump springs.

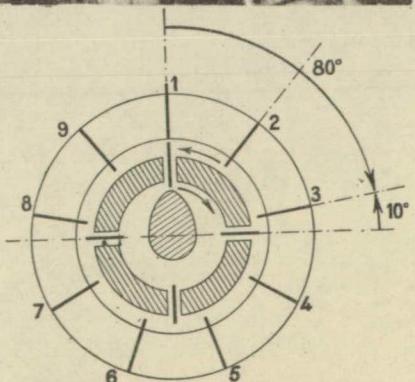


Fig.10 Diagram showing
coincidences, cam, slides
and tappets.

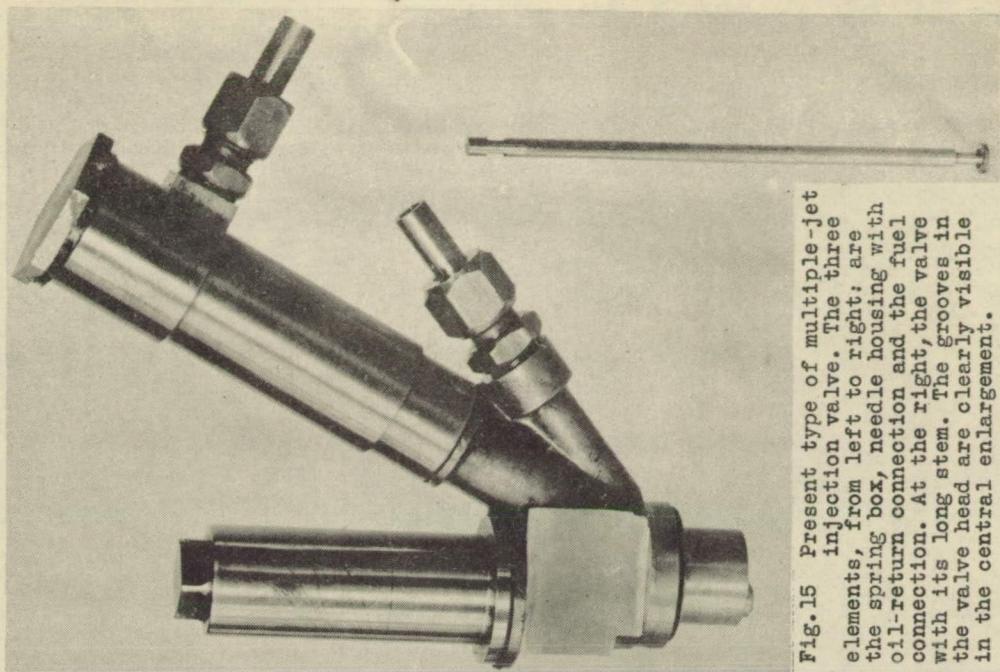


Fig. 13 Principle of pump regulation. Heavy lines B_1C_1 and C_1O : initial positions (corresponding to low speed) of rod T and lever A (Fig. 12). Heavy dash lines B_2C_2 and C_2O : final positions of T and A after rotation α imparted to A by the maximum movement of rod T (B_1C_1). Dotted lines $B_2C'_2$ and C'_2O : positions of the same components after a rotation $\alpha+\beta$ of A made possible by lowering hinge C_1 to C'_1 .

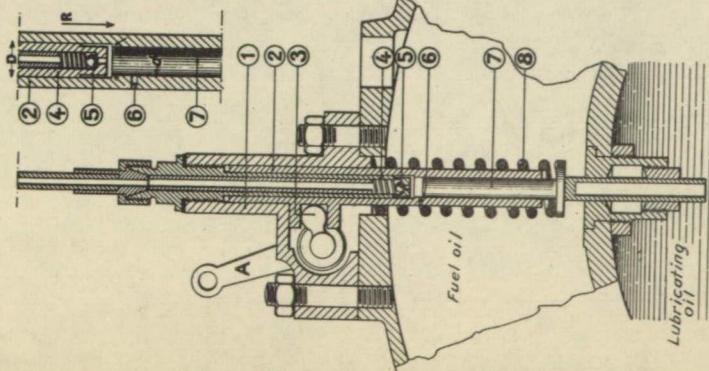


Fig. 11 Diagram of Glerget pump. A , fuel control lever operated by pilot and integral with finger 3; 1, pump barrel mounted on crank-case; 2, movable cylinder shifted by rotation of finger 3; 4, case inclosing ball valve 5; 6, intake orifice; 7, piston recalled by spring 8. Upper right: Cross section on larger scale near valve. Note difference between diameters D and d of cylinder and piston.

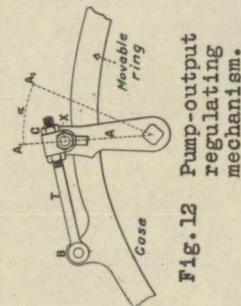


Fig. 12 Pump-output regulating mechanism.

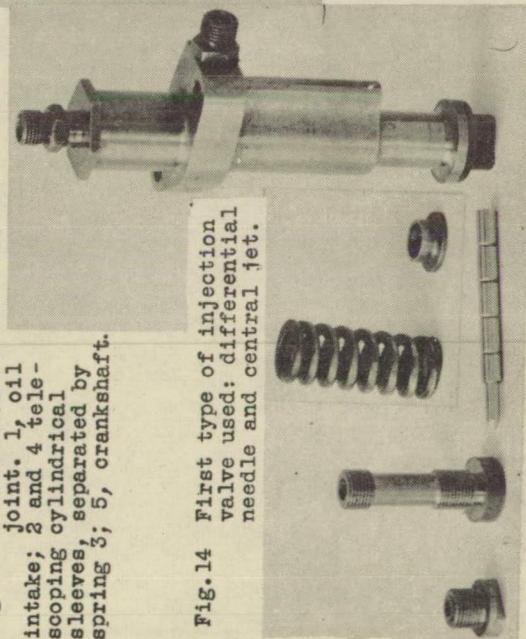


Fig. 14 First type of injection valve used: differential needle and central jet.

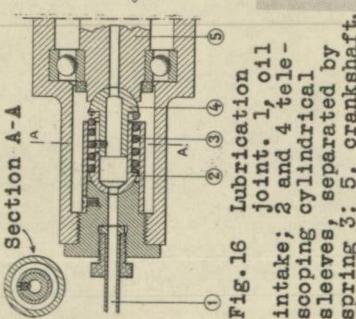


Fig. 16 Lubrication joint. 1, oil intake; 2 and 4 telescoping cylindrical sleeves, separated by spring 3; 5, crankshaft.

Fig. 15 Present type of multiple-jet injection valve. The three elements, from left to right: are the spring box, needle housing with oil-return connection and the fuel connection. At the right, the valve with its long stem. The grooves in the valve head are clearly visible in the central enlargement.